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Uranium and plutonium prompt-fission-neutron energy spectrum (PFNS) from the analysis of NTS NUEX data

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The neutron experiment (NUEX) was a common diagnostic on nuclear device tests conducted at the Nevada Test Site (NTS). In these experiments neutrons from a device pass up a collimated line of site, and in the case of a Faraday cup (FC) NUEX, the neutrons pass through a thin CH_2 foil. Some of these neutrons interact with the nuclei in the foil, generating light charged particles (predominately protons) which are collected in a Faraday cup. The time dependence of the Faraday cup current is a measure of the energy spectrum of the neutrons that leak from the device. With good device models and accurate neutron-transport codes, the leakage spectrum can be converted into a prompt fast-neutron-induced fission-neutron energy spectrum (PFNS) from ~1 to 11 MeV. This has been done for two of our events containing a plutonium primary, where the NUEX data were of a particularly high quality, and one event containing a uranium primary. The fission-neutrons in the device were produced by fission events induced by neutrons over a broad range of energies. We have listed the inferred 1.5 MeV n + ^{239}Pu fission-neutron spectra in Tables 1 to 4 for outgoing neutron energies from 1.5 to ~10.5 MeV, in 1-MeV steps. The uranium device contained a larger high explosive charge. This limited the extraction of the uranium PFNS spectrum to upper neutron energy 9.5 MeV. The listed values represent the fission-neutron emission probability at the quoted outgoing neutron energies and are not the integrals over 1-MeV wide bins. The quoted relative emission probabilities are all relative to the probability of emitting 1.5 MeV neutrons. The presence of the high explosive charge surrounding the fissile material made estimates of the lower energy PFNS (below 1 MeV) problematic. To obtain estimates of the absolute emission probabilities, the low-energy portion of the PFNS was assumed to be as calculated by the Los Alamos (fission) model[1] (LAM). The three NUEX inferred PFNS are labeled Pu-NUEX-1; Pu-NUEX-2; and U-NUEX-1. Pu-NUEX-1 was from an event near the end of US nuclear testing and its data quality was higher than the data associated with the earlier events used to obtain Pu-NUEX-2 and U-NUEX-1.

Table 1. Pu-NUEX-1 : inferred fission-neutron energy spectrum for 1.5-MeV neutron induced fission of ^{239}Pu; and the ratio of the NUEX inferred spectrum to the Los Alamos model. All errors are 1 sigma.

Neutron energy (MeV)	Relative emission probability	Probability (1/MeV)	LAM (1/MeV)	Probability ÷ LAM
1.5	1.000±0.026	0.2902±0.0075	0.2907	0.998±0.026
2.5	0.663±0.017	0.1925±0.0048	0.1913	1.006±0.025
3.5	0.383±0.010	0.1110±0.0029	0.1099	1.010±0.026
4.5	0.209±0.006	0.0608±0.0017	0.0603	1.007±0.028
5.5	0.110±0.004	0.0319±0.0012	0.0323	0.987±0.037
6.5	0.0576±0.0020	0.0167±0.0006	0.0169	0.990±0.034
7.5	0.0294±0.0013	0.00853±0.00037	0.00862	0.990±0.043
8.5	0.0139±0.0011	0.00403±0.00031	0.00434	0.929±0.072
9.5	0.0074±0.0009	0.00215±0.00025	0.00217	0.991±0.116
10.5	0.0046±0.0009	0.00134±0.00025	0.00108	1.241±0.232

Table 2. Pu-NUEX-2 : inferred fission-neutron energy spectrum for 1.5-MeV neutron induced fission of ^{239}Pu; and the ratio of the NUEX inferred spectrum to the Los Alamos model.

Neutron energy (MeV)	Relative emission probability	Probability (1/MeV)	LAM (1/MeV)	Probability ÷ LAM
1.5	1.000±0.041	0.2917±0.0120	0.2907	1.004±0.041
2.5	0.668±0.014	0.1948±0.0041	0.1913	1.018±0.021
3.5	0.381±0.011	0.1110±0.0031	0.1099	1.011±0.028
4.5	0.207±0.009	0.0605±0.0026	0.0603	1.004±0.043
5.5	0.108±0.007	0.0315±0.0020	0.0323	0.974±0.063
6.5	0.0550±0.0043	0.0161±0.0013	0.0169	0.951±0.074
7.5	0.0293±0.0025	0.00854±0.00072	0.00862	0.991±0.083
8.5	0.0148±0.0009	0.00431±0.00025	0.00434	0.993±0.059
9.5	0.00788±0.0008	0.00230±0.00024	0.00217	1.060±0.108
10.5	0.00466±0.0010	0.00136±0.00030	0.00108	1.259±0.273

Table 3. Pu-NUEX : combined Pu-NUEX 1 and 2 fission-neutron energy spectrum for 1.5-MeV neutron induced fission of ^{239}Pu; and the ratio of the NUEX inferred spectrum to the Los Alamos model.

Neutron energy (MeV)	Relative emission Probability	Probability (1/MeV)	LAM (1/MeV)	Probability ÷ LAM
1.5	1.000±0.025	0.2905±0.0073	0.2907	0.999±0.025
2.5	0.670±0.014	0.1945±0.0041	0.1913	1.017±0.021
3.5	0.382±0.009	0.1110±0.0027	0.1099	1.011±0.024
4.5	0.209±0.005	0.0607±0.0016	0.0603	1.005±0.026
5.5	0.110±0.004	0.0318±0.0011	0.0323	0.985±0.033
6.5	0.0573±0.0019	0.0166±0.0005	0.0169	0.986±0.033
7.5	0.0294±0.0012	0.00853±0.00035	0.00862	0.990±0.041
8.5	0.0145±0.0007	0.00421±0.00022	0.00434	0.970±0.049
9.5	0.00771±0.0007	0.00224±0.00019	0.00217	1.032±0.088
10.5	0.00465±0.0008	0.00135±0.00023	0.00108	1.250±0.210

Table 4. U-NUEX : inferred fission-neutron energy spectrum for 1.5-MeV neutron induced fission of ^{235}U; and the ratio of the NUEX inferred spectrum to the Los Alamos model.

Neutron energy (MeV)	Relative emission Probability	Probability (1/MeV)	LAM (1/MeV)	Probability ÷ LAM
1.5	1.000±0.022	0.2947±0.0065	0.2921	1.009±0.022
2.5	0.639±0.014	0.1884±0.0041	0.1903	0.990±0.022
3.5	0.361±0.008	0.1063±0.0023	0.1050	1.013±0.022
4.5	0.190±0.004	0.0559±0.0013	0.0554	1.009±0.023
5.5	0.0940±0.0035	0.0277±0.0010	0.0286	0.969±0.036
6.5	0.0487±0.0021	0.0144±0.0006	0.0144	0.997±0.044
7.5	0.0216±0.0023	0.00638±0.00068	0.00706	0.903±0.097
8.5	0.00989±0.0020	0.00292±0.00060	0.00340	0.857±0.176
9.5	0.00309±0.0021	0.00091±0.00061	0.00163	0.558±0.375

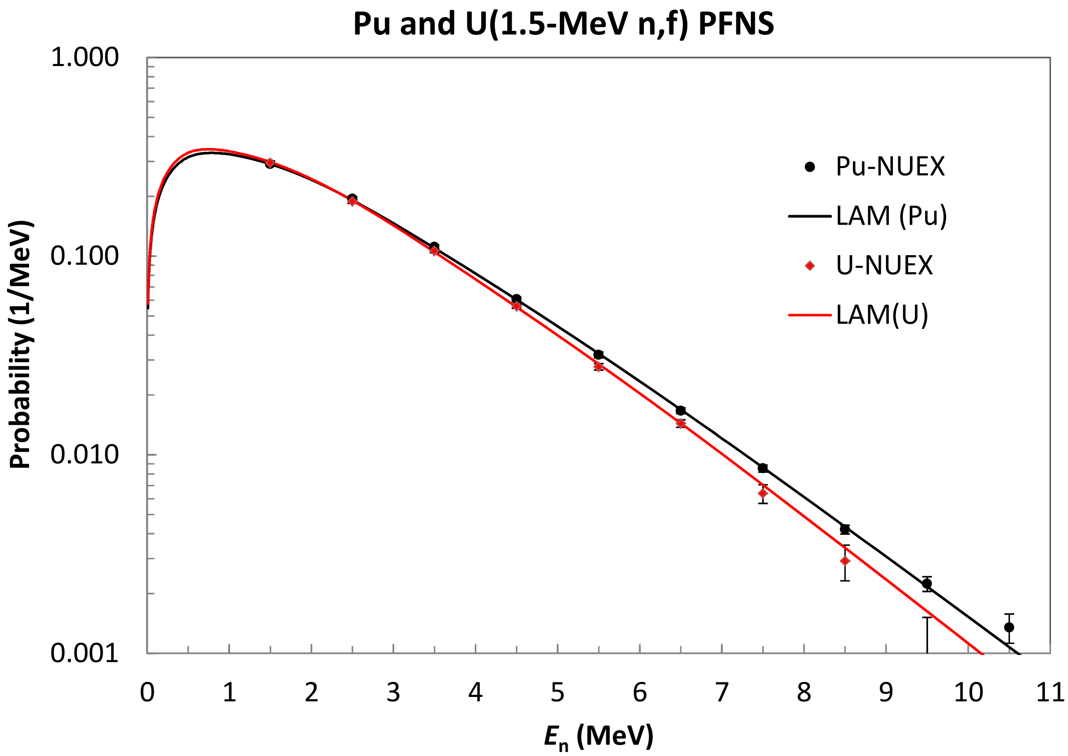

Fig. 1. The emission probabilities listed in Tables 3 and 4, and the corresponding 1.5-MeV n + ^{239}Pu and ^{235}U Los Alamos fission model fission-neutron energy spectra[1] (curves).

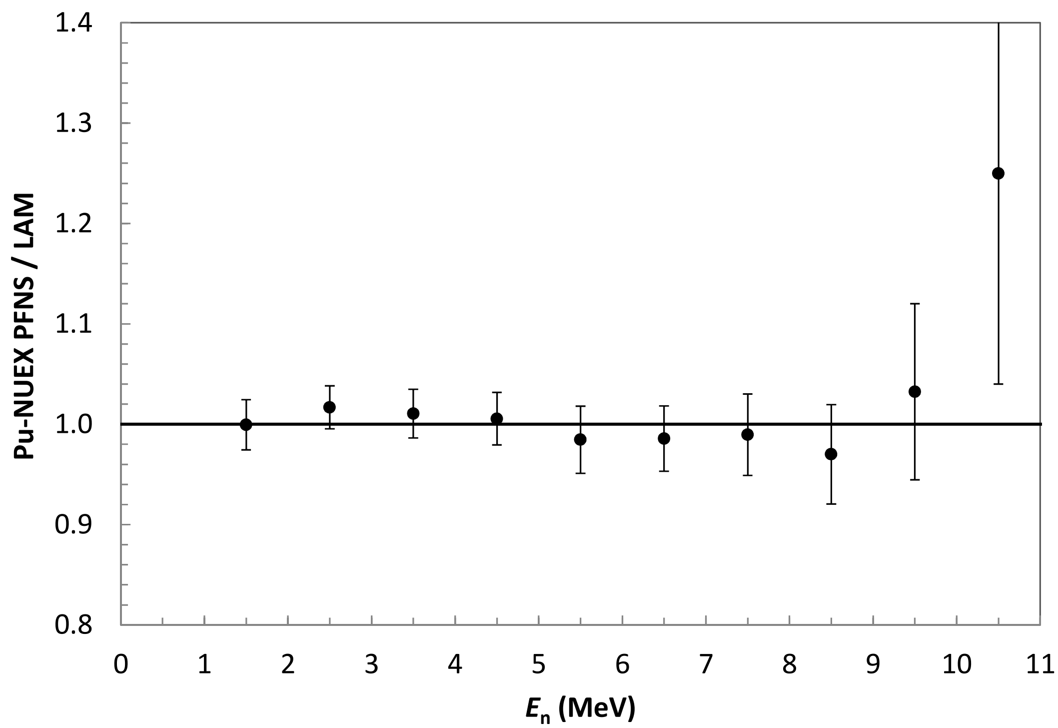

Fig. 2. Ratio of the Pu-NUEX inferred ^{239}Pu(1.5-MeV n,f) PFNS to the Los Alamos fission model (see Table 3).

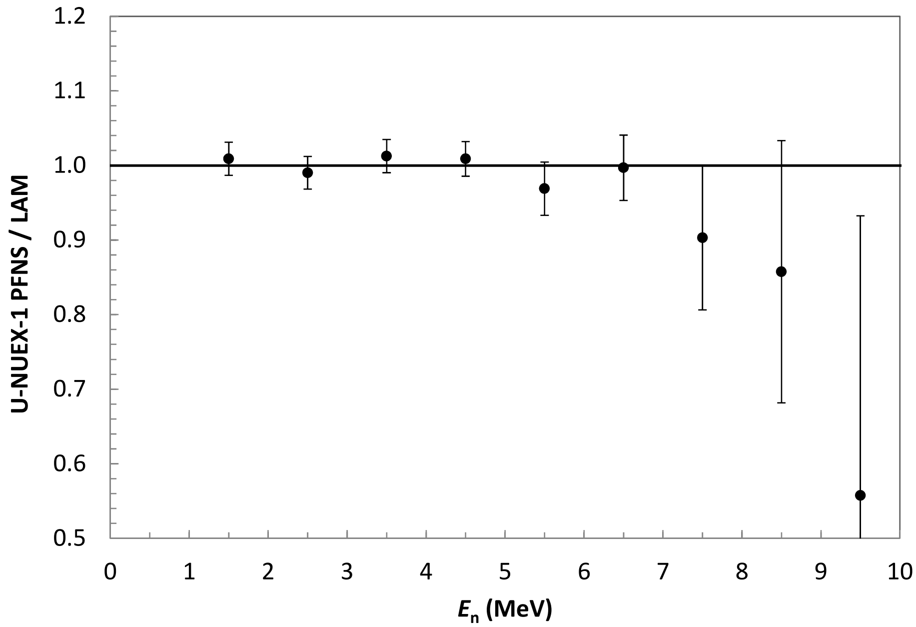

Fig. 3. Ratio of the U-NUEX inferred ^{235}U(1.5-MeV n,f) PFNS to the Los Alamos fission model (see Table 4).

There are common systematic uncertainties associated with both the Pu-NUEX and U-NUEX which cancel if the ratios of these two results are taken. These ratios are thus a good test of the Los Alamos fission model. Fig. 4 compares the ratio of Pu-NUEX to U-NUEX results to the corresponding ratios from the Los Alamos fission model.

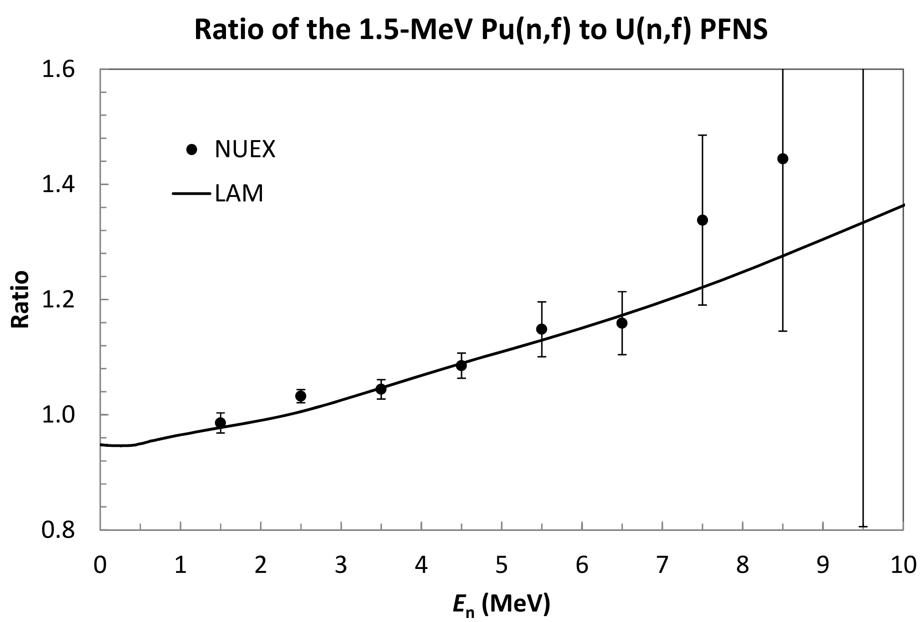

Fig. 4. A comparison of the ratio of Pu-NUEX to U-NUEX PFNS results to the corresponding ratios from the Los Alamos fission model.

[1] D. G. Madland and J. R. Nix, Nucl. Sci. and Eng. **81**, 213 (1982), and http://t2.lanl.gov/data/fspect.